Pilot Green Transport Fund

Final Report
On
Trial of Diesel-Electric Propulsion System for Ferry II
(The "Star" Ferry Company, Limited)

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(Reporting Period: 1 June 2020 – 31 May 2022)

Executive Summary

1. Introduction

1.1 The Pilot Green Transport Fund (the Fund) is set up to encourage transport operators to try out green innovative transport technologies, contributing to better air quality and public health for Hong Kong. The "Star" Ferry Company, Limited (Star Ferry) was approved under the Fund for trial of one diesel-electric propulsion (DEP) system by retrofitting it to an existing ferry (Morning Star). The DEP system replaced the ferry's original diesel engine. The DEP system was expected to mainly lower the air pollutants emissions of the ferry. Through the tendering procedures stipulated in the Subsidy Agreement entered into with the Government, Star Ferry appointed Leung Wan Kee Shipyard to retrofit the DEP system on Morning Star (hereafter called DEP ferry) for trial.

1.2 Star Ferry assigned a conventional ferry, Northern Star, providing the same service as the DEP ferry as the conventional counterpart for comparing with the DEP ferry. Northern Star is referred to as conventional ferry in this report.

1.3 PolyU Technology and Consultancy Company Limited has been engaged by the Environmental Protection Department as an independent third party assessor to monitor the trial and evaluate the performance of the green innovative technology under trial as compared with its conventional counterpart. Star Ferry commissioned an expert team of The University of Hong Kong (HKU) as their contractor to conduct the air pollutants emission measurements.

1.4 This report summarizes the performance of the DEP ferry in the 24 months of the trial and compares it with the performance of the conventional ferry.

2. Trial Ferry and Conventional Ferry

2.1 The DEP system includes two 275 kW Caterpillar diesel generators, two frequency inverters and two 350 kW electric motors and the associated control equipment. The two 275 kW generators meet International Maritime Organization (IMO) Tier II and United States Environmental Protection Agency (USEPA) Tier III emission standards. The DEP ferry is designed to operate with two generators simultaneously in normal operation. In case one of the generators is out of order, the other generator can operate the motor in the power limited mode. The two frequency inverters are used to control the operation of the

electric motors. The DEP system replaced the ferry's original 357 kW pre-1990 diesel engine.

2.2 Key features of the DEP system, the DEP ferry and the conventional ferry are in Appendix 1, and photos of the DEP system, the DEP ferry and the conventional ferry are in Appendix 2. The DEP ferry provides round trip service from Tsim Sha Tsui Pier to Wan Chai Pier or Central Pier.

3. Trial Information

3.1 The trial started on 1 June 2020 and lasted for 24 months. Star Ferry was required to collect and provide trial information including the DEP ferry operation data and maintenance records. DEP ferry operation data include passenger carried, operating hours, amount and cost of diesel fuel consumed. Maintenance records include cost and downtime associated with scheduled and unscheduled maintenances of the DEP ferry related to the performance of the DEP system. Similar data were also required from the conventional ferry. In addition to the cost information, reports on maintenance work, operational difficulties and opinions of the captains of the DEP ferry, passengers and Star Ferry were collected to reflect any problems of the DEP ferry.

3.2 Since the Government tightened the statutory fuel sulphur content from 0.5% to 0.05% in 2014, the sulphur dioxide (SO_2) emission in the exhaust gas has dropped significantly and the DEP system's contribution to the SO_2 emission reduction has been small. Hence, the DEP system is mainly used to reduce the emissions of nitrogen oxides (NOx) and particulates (PM). The exhaust emissions had been measured before Morning Star was retrofitted with the DEP system and measured again in the first month of trial (June 2020), in the 12th month of trial (June/July 2021) and in the 24th month of the trial (May 2022). The exhaust emissions measured mainly included the concentrations of NOx and PM, as well as smoke opacity. Meanwhile, concentrations of carbon monoxide (CO) and hydrocarbons (HC) were also measured in this trial for reference. Star Ferry commissioned an expert team of HKU as their contractor to conduct the aforesaid emission measurements.

4. Findings of Trial

4.1 The trial was considered to be in a preliminary trial stage for the months of June 2020 to August 2020 as Star Ferry was familiarizing/testing the performance and characteristics of the engine and the ferry though started providing ferry services, the data collected in those months were less representative. The DEP ferry resumed to normal operation from September 2020 onwards and the evaluation was therefore taken from September 2020 onwards.

4.2 In the beginning of the trial, Star Ferry operated the DEP ferry with one generator in order to reduce fuel consumption. However, the ferry has shown trouble in operating with one generator. At high load and during manoeuvring operations, the frequency inverter alarm sometimes might be actuated causing tripping to the frequency inverter(s) and the

motor(s). Such conditions could be significantly avoided when two generators were put to use simultaneously. Hence, the DEP ferry was operated with two generators from September 2021 onwards.

4.3 Table 1 summarizes the statistical data of the DEP ferry and the conventional ferry from 1 September 2020 to 31 May 2021. The average fuel cost of the DEP ferry was HK$20 per hour (2.7%) lower than that of the conventional ferry. The average total operating cost of the DEP ferry was HK$171 per hour (16.4%) lower than that of the conventional ferry.

Table 1: Key operation statistics of ferry (1 September 2020 – 31 May 2022) [1]

	DEP Ferry	**Conventional Ferry**
Total time travelled (hour)	6,604	6,373
Average fuel consumption (litre/hour)	34.2	35.0
Average fuel cost (HK$/hour) [2]	711	731
Average total operating cost (HK$/hour)	874	1,045
Downtime (working day) [3]	78	103

[1] As June 2020 – August 2020 were in preliminary trial stage and the data of the DEP ferry were less representative, therefore, the evaluation was taken from September 2020 to May 2022.

[2] Based on the listed price of marine light diesel.

[3] Downtime refers to the working days the ferry was not in normal operation, which is counted from the first day it stopped normal operation till the day it resumed normal operation.

4.4 In the period of 1 September 2020 to 31 May 2022, the DEP ferry had 8 scheduled maintenances and 22 unscheduled maintenances with a total of 78 days of downtime, while the conventional ferry had 8 scheduled maintenances and 28 unscheduled maintenances with a total of 103 days of downtime. The utilization rates were 87.8% for the DEP ferry and 83.9% for the conventional ferry.

4.5 In the period of September 2020 to May 2022, some captains had comments on operating the DEP ferry that they pointed out the tripping problem of the DEP system when one generator was being used in high load and reverse-manoeuvring conditions. Comparing with the Conventional Ferry, they indicated that operations of DEP ferry was more innovative and complicated, which took more time to adapt. As advised by Star Ferry, to address the above tripping problem, the DEP ferry was changed to operate with two generators from September 2021 onwards. Nevertheless, some other opinions in general reflected that the DEP ferry was noisier compared with the conventional ferry. Star Ferry agreed that the DEP ferry could help improve the air quality but had reservation in retrofitting the diesel engines of all existing conventional ferries with the DEP systems because it did not help reducing the fuel cost much, it was not easier to maintain as expected and it could not be stably operated with one diesel generator only. The passengers' feedback was in general positive, feeling that it is cleaner and quieter, and support retrofitting the existing ferries with the DEP system.

4.6 The 12-month moving average fuel economy of the DEP ferry increased from 34.3 liter/hour to 34.7 liter/hour, which was about 1%. The results showed that there was almost no change in the fuel economy of the DEP ferry in the 24-month trial period.

4.7 In the 24-month of the trial, the carbon dioxide equivalent (CO_2e) emission from the DEP ferry was 591,216 kg, while that from the conventional ferry based on DEP ferry's mileage was 605,645 kg. There is a reduction of 14,429 kg (about 2.4%) CO_2e emission by using the DEP ferry.

5. Reduction of Air Pollutants Emissions

5.1 The DEP system is mainly used to reduce the emissions of nitrogen oxides (NOx) and particulate matters (PM) compared to the old engine. The emissions were measured in March and April 2019 for the original ferry (i.e., before retrofit). The emissions were measured again in June 2020 for the DEP ferry (i.e., after retrofit), in June/July 2021, which was about 12 months after the retrofit, and in May 2022, which was about 24 months after the retrofit.

5.2 In the 24 months after the retrofit, NOx emission was reduced by 63% while PM emission was reduced by 75%.

5.3 Carbon monoxide (CO) and hydrocarbons (HC) emissions were also measured in this trial for reference. About 24 months after the retrofit, the CO and HC emissions were reduced by 6% and 57% respectively.

6. Summary

6.1 The trial was considered to be in a preliminary trial stage in the first three months of the trial (June to August 2020) as Star Ferry was familiarizing/testing the performance and characteristics of the engine and the data collected were less representative. Therefore, the evaluation was taken from September 2020 to May 2022 in this report.

6.2 In the 24 months of the trial, the utilization rates were 87.8% for the DEP ferry and 83.9% for the conventional ferry. The average fuel cost of the DEP ferry was HK$20 per hour (2.7%) lower than that of the conventional ferry. The average total operating cost of the DEP ferry was HK$171 per hour (16.4%) lower than that of the conventional ferry.

6.3 The trial showed that under local operating conditions, the DEP system could meet the user's operational requirements and cope with the required tasks only when operating with two diesel generators. The captains of the DEP ferry had varied opinions on the performance of the DEP ferry. Some indicated that the DEP ferries were more innovative and complicated to operate than the conventional ferries during the trial period. However, in general they reflected that the DEP system was noisy.

6.4 Star Ferry agreed that the DEP ferry could help improve the air quality but had reservation in retrofitting the diesel engines of all existing conventional ferries with the DEP systems because it did not help reducing the fuel cost much, it was not easier to maintain as expected and it could not be stably operated with one diesel generator only.

6.5 The passengers' feedback was in general positive, feeling that it is cleaner and quieter, and support retrofitting the existing ferries with the DEP system.

6.6 The 12-month moving average fuel economy of the DEP ferry increased from 34.3 liter/hour to 34.7 liter/hour, which was about 1%. The results showed that there was almost no change in the fuel economy of the DEP ferry in the 24-month trial period.

6.7 The emissions measurement results reflected that the replacement of the old engine with the DEP system reduced the emissions of NOx and PM by 63% and 75% respectively, and reduced the CO and HC emissions by 6% and 57% respectively, at the end of the 24 months of trial.

Appendix 1: Key Features of the Ferries Involved in the Trial and the Diesel-electric propulsion system

1. Diesel-electric propulsion (DEP) system for DEP ferry

Main Generator Set (two sets)

Maker:	Caterpillar
Model:	C9.3 Marine Generator Set
Rating:	275 kW @1800 rpm
Engine:	6-cylinder in line diesel engine
Emission standard:	EPA Tier 3/IMO II

Auxiliary Generator Set (two sets)

Maker:	Perkins
Model:	1004TGM
Rating:	52 kW @ 1500 rpm

Propulsion Motor (two sets)

Maker:	Dezhou Hengli
Model:	YVF2-4003-6-H
Rating:	350 kW @ 1190 rpm

2. DEP Ferry

Name of vessel:	**Morning Star**
Type:	Class I Ferry Vessel
Port of Registry	Hong Kong
Length overall:	35.61 meters
Extreme breadth:	8.57 meters
Light Ship Displacement:	235.47 / 250.10 tonnes(without balast / with ballast)
Gross Tonnage:	206 / 164.01 tonnes (after retrofit / before retrofit)
Net Tonnage:	100 / 39.69 tonnes (after retrofit / before retrofit)
Passenger capacity:	399 / 540 people (after retrofit / before retrofit)
Year of manufacture:	1965; retrofitted with DEP in 2020

3. Conventional Ferry for comparison purpose

Name of vessel:	**Northern Star**
Type:	Class I Ferry Vessel
Length overall:	35.63 meters
Extreme breadth:	8.57 m
Light Ship Displacement:	248.55 tonnes
Gross Tonnage:	164.01 tonnes
Net Tonnage:	39.69 tonnes
Passenger capacity:	547 people
Year of manufacture:	1958
Main engine:	Crossley/6HRN; 340 rpm, 357.33 kW
Generator set:	2*Perkins 1004TGM; 52 kW @ 1500 rpm

Appendix 2: Photos of the Ferries and the Diesel Electric Propulsion System

1. DEP Ferry and DEP system

	
Front view of DEP Ferry – Morning Star	Side view of DEP Ferry – Morning Star
	
#1 main diesel generator (for propulsion)	#2 main diesel generator (for propulsion)
	
Auxiliary diesel generator	Propulsion motor

2. Conventional Ferry

Northern Star